BLOOD FLOW AND PRESSURE CHANGES THAT OCCUR WITH TILT-IN-SPACE

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Introduction

The overall objective of our research is to improve the use of seated tilt to increase function, health and quality of life for people using power wheelchairs. Specifically, the goal of this project is to evaluate the biomechanical responses to seated full body tilt.

Tilt systems are frequently prescribed to wheelchair users who are unable to independently reposition or perform pressure reliefs. However, little is known about the biomechanical effects of their use.

Pressure ulcers remain a major problem for many wheelchair users [1]. In addition to having an obvious detrimental impact on health, pressure ulcers often disrupt the educational, vocational and community participation of wheelchair users, thus negatively affecting quality of life. Two factors, the magnitude of pressure and duration of loading, are the defining causes of pressure ulcers [2, 3]. Clinically, these causative factors are addressed by the selection of an appropriate seating system, including a pressure distributing wheelchair cushion, and by the establishment of pressure relief schedules. Power wheelchair users who are unable to independently perform pressure reliefs are often prescribed powered tilt systems.

The Consortium for Spinal Cord Medicine suggested that tilt systems be utilized to perform weight shifts every 15-30 minutes for at least one minute [4]. Although the required tilt angle to perform a pressure relief has not been defined, research has shown that interface pressure decreases as the tilt angle increases. Therefore, recommendations in the literature and clinic vary from 30° to 65°, with an emphasis on tilting "all the way back".

In this study, Laser Doppler flowmetry and interface pressure measurement were employed to measure the increase in blood flow and decrease in loading with increased tilt angle on participants with SCI.

Methods

This study was approved by the local institutional review boards and participants signed informed consent prior to participation. Eleven participants with SCI who used power tilt-in-space wheelchairs were recruited to participate. Measurements of superficial blood flow were done using the PeriFlux 5010 LDPM (Laser Doppler Perfusion Monitor) and a custom probe (Figure 1, LEFT). A custom sensor from FSA (Vista Medical, Winnipeg, Manitoba) was utilized to monitor the localized loading surrounding the LDFM probe.

Initially, participants donned a pair of stretchy boxer shorts and were lifted with an overhead lift and a Guldman net to provide access to the ischial region while maintaining a relatively upright, seated posture. With

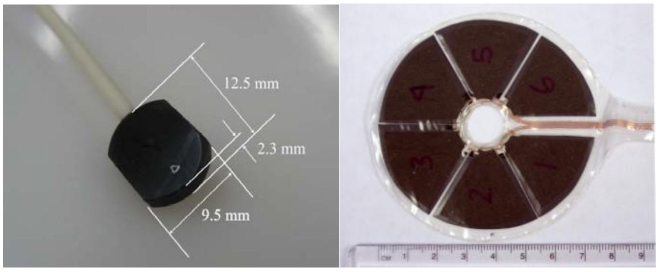

Figure 1. (LEFT) LDPM probe. (RIGHT) Interface pressure sensor.

the subject lifted, the interface pressure sensor and LDPM probe were attached to the skin directly superficial to the apex of the ischial tuberosity.

Three randomized trials of the following, alternating sequences were performed in the participants' personal wheelchairs. Sequences included Upright (or minimum tilt position) → 15°, Upright → 30°, Upright → 45°, and Upright → maximum tilt. All seated positions were held for 2 minutes and trials were separated by 5 minutes of unloaded sitting (lifted in the Guldman net). LDFM was sampled at 32 Hz and the interface pressure sensor was sampled at 1 Hz throughout the duration of the above testing.

All data analysis was performed with Matlab R2008a (Mathworks Inc, Natick, MA). Average blood flow was calculated as the average reading over the final minute at each position. Blood flow at each tilted position was normalized by blood flow at the preceding upright position. Maximum pressures across all sensels were analyzed. All statistical comparisons were computed with paired, one sided t-tests.

RESULTS

Subjects included 9 men and 2 women with mean (SD) height 1.79m (0.04m) and weight 80kg (14kg). Seven subjects were African American, 3 were white, and 1 identified as biracial. Research participants had been using a wheelchair for a mean (SD) of 9.4 (5.7) years, with a minimum of 9 months and a maximum of 18 years.

Wheelchair configurations were not modified for this study. The upright position in all chairs was less than or equal to 5° (mean (SD) = 2.1° (1.8°)). Seat to back angles ranged from 90° – 110°, with a mean (SD) of 101° (6°).

Tilt Position	Max Pressure (mmHg)	Mean Pressure (mmHg)	Mean Normalized Blood Flow
Upright	91 (32)	74 (27)	n/a
15°	87 (30) NS	71 (25) †	1.08 (0.19), p=0.016
30°	77 (28) †	62 (24) †	1.24 (0.48), p = 0.003
45°	63 (25) †	50 (21) †	1.84 (1.84), p=0.007
55°	68 (27) †	53 (23) †	3.34 (5.09), p=0.034

Table 1. Absolute pressure and normalized blood flow at each position – averaged across subjects. Statistics were computed on tilted pressure measures paired with upright and for normalized blood flow compared with a ratio of 1. Mean (SD). † p<0.001, NS p>0.05. Note: Only 6 participants' data are included at 55° due to maximum positions of the wheelchairs.

Peak pressures in the region surrounding the ischial tuberosity in upright sitting varied across participants from 27 to 176 mmHg (). Although there was no decrease in pressure at 15°, there were significant decreases at all other tilt positions.

	35° Tilt		45° Tilt		55° Tilt	
Pressure in Upright (mmHg)	mmHg	%	mmHg	%	mmHg	%
50	41	82	34	67	27	53
100	81	81	74	74	66	66
150	122	81	115	76	107	72

Table 2. Estimated maximum pressures based on Equations 1 and 2. Estimated mean pressures are nearly identical.

We used multivariate linear regression to create a model to predict the maximum pressure based on tilt angle: $\text{MaxPressure}_{\text{Tilted}} = 25.6 - 0.718*\text{Angle} + 0.809*\text{MaxPressure}_{\text{Upright}}$ ($R^2 = 88.1$). This model is individualized based on the initial, upright pressure. All coefficients in the model were significantly different than zero ($p<0.001$). Because interpretation of a multivariate model can be confusing, Table 2 presents some examples of what the model would mean at a 35°, 45° and 55° of tilt for people with different initial loads.

Blood flow results were highly varied across subjects. For instance, only five subjects appear to have blood flow that increases monotonically with tilt angle. Two subjects had limited or no increase in flow with tilts up to 45° but had considerable blood flow increases at maximum tilt. On average, all tilt positions resulted in a significant increase in blood flow. Although it was statistically significant, the increase in blood flow at 15° of tilt was only 8% and was highly variable across subjects (SD = 19%) (). Nine of the eleven participants showed a considerable increase in blood flow at the terminal tilt position available on their wheelchair. On the other hand, only 4 of 11 participants had an increase in blood flow of ≥ 10% at 30% tilt.

DISCUSSION

This study produced a number of interesting results: 1) A significant increase in blood flow at 15° of tilt was not accompanied by a drop in pressure, suggesting a different mechanism for the increase in blood flow. 2) Changes in blood flow and pressure are highly individualistic. 3) Terminal tilts (45°-55°) produced the largest changes in pressure and blood flow across the most subjects.

Based on these results, we can offer some preliminary guidelines for pressure relieving tilts. First, we would recommend tilting for pressure reliefs as far as the seating system permits. Additionally, until we understand more, we should not neglect the potential impact of small tilts. As described previously, the increase in blood flow due to small tilts cannot be attributed entirely to a decrease in pressure. Therefore, it is unknown whether these small tilts might provide a different benefit to the body from the weight shifts at a full tilt. As described in earlier research [5], small tilts also have many functional benefits over large tilts and might be a helpful option in between large tilts.

These preliminary guidelines for a pressure relieving tilt must be interpreted cautiously. With only 11 participants, most of whom were sitting on a Roho air inflation cushion, it is unclear whether the results will generalize to a larger population and other wheelchair cushions. For example, in Stockton and Rithalia's blood flow work, they found that forward leans on a Roho resulted in a smaller pressure reduction and blood flow increase compared to a gel cushion, suggesting tilts might have greater pressure reduction and blood flow increase for participants on a gel cushion [6]. However, the recommendation put forth in this study does err on the side of caution. Future research will hopefully be able to individualize the guidelines based on personal characteristics.

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